The Galvanometric Measurement of Human Emotion.[1]

By DR. A. D. WALLER, F.R.S.

WE are all of us familiar, subjectively within ourselves, objectively by the behaviour of our neighbours, with the signs and symptoms of emotion, and with the fact that such signs and symptoms are more or less under voluntary control and can be suppressed or simulated at will. We are moved to or from an object we may desire or fear. We are moved to laughter or to tears by events witnessed and imagined; and whereas all men are moved in the mass by the same general motives of light and dark, food and hunger, love and hate, we know by everyday experience that no two men react in identical fashion to the same motives.

1. Physiologically, all emotions are expressed as neural outbursts from the central nervous system through efferent nerves to muscles and glands; emotion, in general, results in intensified physiological activity at the periphery of the body—muscles and glands, heart and blood-vessels, the face and eyes and skin. A movement of surprise, a palpitation of the heart, a blush, a pallor, a shiver, a rush of tears, a dilated pupil—all these and other signs of emotion consist in sudden local intensifications of the chemical exchanges that are in constant operation between the living cells of the body and the fluid medium by which they are surrounded. We know indeed that all such chemical exchanges are controlled through efferent nerves, and we speak of this control as their trophic action, but we are scarcely prepared at the present day to recognise the close association between signs of emotion and the phenomena of nutrition.

2. The physical sign of emotion is known to psychologists as the psycho-galvanic reflex. It was first definitely revealed to us twelve years ago by Veraguth,[2] of Zurich, and has since then formed a favourite subject of study by many later observers whom I shall not attempt to enumerate. I joined in the hunt four years ago,[3] and was very quickly satisfied that this physical sign affords the most convenient possible gauge and measure of human character and of human temperament, seeing that it declares *how much* a given subject is moved by his thoughts and feelings. A spot of light showing the movements of a galvanometer connected with the palm of the hand exhibits the fluctuating emotions of the person to whom the hand belongs, and if the person be an ordinary normal person it is only the palm of the hand, and not any other part of the skin of the upper extremity, that shows the response. My first point is, then, that the emotive response is, *par excellence*, a palmar phenomenon, and I shall, as my first and chief experiment, undertake to demonstrate this point. (Experiment.)

3. Mr. X. Y. has been good enough to lend himself to my purpose. His hand and his forearm are connected with each of two galvanometers and two Wheatstone bridges. The round spot belongs to the hand circuit, the square spot to the forearm circuit, and balance can be adjusted in each circuit separately by suitable manipulation of the two resistance boxes. In both cases the wiring is such that increased conductivity of the hand or of the forearm gives movement of the spots to my right, *i.e.* any emotive impulses from the brain down motor nerves to the hand or to the forearm will cause deflection to the right. Let us watch the two spots for a while. I expect you to see that the hand spot behaves irregularly, whereas the arm spot creeps steadily across the scale without showing any of the vagaries of the round spot.

You realise now why I have been at trouble to show the simultaneous behaviour of *two* spots. With only the hand in circuit of one galvanometer you should at first have felt doubtful whether the movements you saw were really due to emotive discharges, and not to otherwise imperceptible muscular twitchings such as are perceived and utilised by thought-readers. It would otherwise have been desirable to set up some very delicate form of myograph to satisfy this doubt. I shall show you presently, by asking the subject to make a least possible movement of one of his fingers, that the round spot—*i.e.* that indicating the electrical resistance of the hand—shows a deflection which is due to a minute disturbance of contact, and, therefore, takes place in the direction opposed to that of an emotive response. I am sure you will realise with me what a mercy it is that the deflection by slight, often quite unavoidable, movement is, in general, the contrary of that of the emotive response.

4. But to return to our experiment. The subject is at rest; both spots are reasonably steady, but by reason of his past experience he knows that an evil moment is approaching. As you may see by the irregular movements of the hand spot, he is beginning to worry, making a picture in his mind of the pain he is about to undergo by steel or fire, and, obviously, this disturbance of quietude creates a condition that is not favourable for recognising or measuring the disturbing effect of any real interference with his comfort. The emotive effects of my threatening language must be allowed to subside. You cannot expect to study rings made by throwing a stone into a pond unless the pond is quiet; you must wait for it to get still. When he comes to rest Mr. X. Y. will react smartly and obviously in response to the suddenly threatened pin-prick or to a real pin-prick. (Trials by pin and matches. Real and imaginary pin-pricks and burns.)

You now, perhaps, feel fairly well satisfied that the statement made a few minutes ago is correct. In the upper limb of a normal person emotive responses to slight excitations are confined to the palm of the hand. The only other part of the body in which they occur is the sole of the foot, but this I shall ask you to take on trust; it really is not necessary that the actual evidence should be brought into court. It would merely be a repetition of what you have just witnessed; and this lantern-plate (Fig. 1) will, after all, afford us the quickest, as well as the most conclusive, evidence.

5. I shall venture to trespass just a little further upon Mr. X. Y.'s endurance to make good one further point, although it is a point that you may already have noticed.

This palmar emotive response is, in my view, to be regarded as caused by a sudden augmentation of electrical conductivity in a membrane or membranes in the fourth arm of the Wheatstone square. That augmentation of conductivity is to be understood as produced by a sudden dilatation of ultramicroscopic pores in this membrane or membranes. I am not speaking of visible pores, but of invisible pores such as are postulated in theories of electrical conduction and of osmotic phenomena. I imagine that these invisible pores suddenly dilate when the emotive impulse through efferent nerves reaches the living membrane, just as we see the pupil of the eye dilate with an emotion of surprise. And with this image in my mind I find it extremely interesting to recognise and measure what a very long time it takes for any given stimulus to produce its effect. It takes two seconds before the threat of a pin-prick—or, for the matter of that, an actual pin-prick—or a single induction shock, brings about the sudden dilatation of pores or increased permeability and the increased electrical conductivity that are signified to us by the movement of the spot of light. How is this long lag of two seconds to be accounted for? Does it occur on the afferent side? Assuredly not. A delay of this sort might be expected to amount to at most one-fifth of a second. Moreover, if we miss out the afferent side altogether, and bring about the response by an artificial explosion down efferent nerves, we shall find the same long delay of two seconds between the muscular movement and the emotive movement, both of which are taking place at the periphery. Therefore, the chief business of the long delay takes place at the periphery, in the skin of the palm of the hand, and its great length is a token that we have to do with impulses conveyed, not along cerebrospinal, but along sympathetic nerves We may find time later to discuss the question whether these are vasomotor or secretomotor or trophic nerves.

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[1] A discourse delivered at the Royal Institution on February 4.

[2] "Das Psychogalvanische Reflexphenomen." (Berlin, 1900.)

[3] "The Galvanometric Measurement of 'Emotive' Physiological Changes." Proceedings of the Royal Society, B, vol. xc., p. 214, 1917.

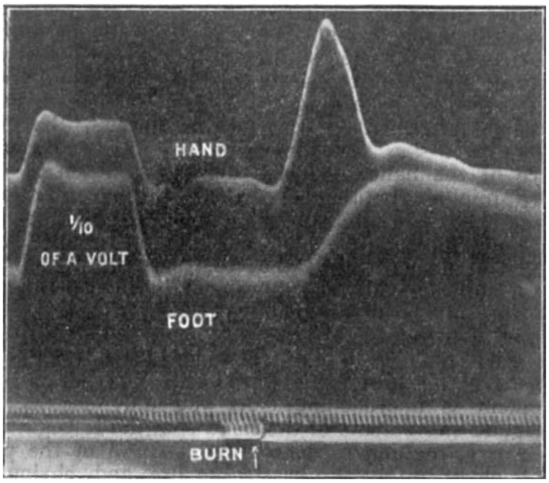

Fig. 1.—This photogram is the simultaneous response of the hand and of the foot of a normal subject, and is given as an example to illustrate the method of investigation by double response. In this example it is evident: (1) that the response occurs sooner and is of shorter duration in the hand (palm) than in the foot (sole) From the time record it can be seen that the lost times in the hand and in the foot are respectively 2 and 4 seconds (approx.), and the durations of response 15 and 40 seconds (approx.). A closer approximation to true time values would require a quicker record to be taken for the lost times and a slower record for the durations. (2) That the response is greater in the hand than in the foot. This magnitude is measured by reference to the initial deflections made by passing a current from $\frac{1}{10}$ volt through each of the two circuits. In this example the hand response is approximately $\frac{1}{10}$, and the foot response approximately $\frac{2}{10}$. The rate of movement of the plate is shown (not very distinctly) in half-seconds. The portion shown in the figure occupied about 45 seconds. A similar procedure by simultaneous double response is required for the mapping out of the body-surface. Obviously the comparison between right and left sides, upper and lower extremities, distal and proximal parts, flexor and extensor aspects, is to be carried out with far greater expedition and certainty by double than it could be by single records.

6. *Dreams* are subjective phenomena occurring in the subconscious state, with which we are all familiar during sleep, and during the hypnotic state, and in the state called "trance." We are familiar also with innumerable objective signs of such subjective phenomena in the shape of descriptions of dreams and in the behaviour of sleep-talkers and sleep-walkers, and, above all, in the extraordinary cases of spiritualistic mediums. These last stand highest in the scale of sensitiveness.

The relative magnitudes of response to a real pin-prick and to a fictitious pin-prick vary with different people under different conditions, but in general they may be divided into two categories, whom we may call *positives* and *imaginatives*.

Positives—in whom little or no disturbance is caused by the threat of a pin-prick, and a real pin-prick is required before any response takes place.

Imaginatives—in whom a large response occurs to the threat—larger, it may be, than the response to the real fact. In not a few of this imaginative class it is almost impossible to take a pure observation of response to fact, for they begin to respond as soon as the operator makes the slightest movement, or else the response is a large one, compounded of fear followed by fact. Here is a confirmatory experiment in evidence of what may be characterised as a dwindling fear and its revival by fact. (Experiment.)

All men (and, judged by their behaviour, animals also) are more or less imaginative. The kind of diagram you have just seen would represent the responses of nine out of ten of my present hearers to a series of threats with a real shock interpolated in the series. Many of us had an opportunity a few years ago of studying upon our friends and upon ourselves the signs and symptoms of fear during German air raids upon what they called the fortified city of London. The noise and disturbance occasioned by these raids, the false alarms and the warnings by maroons and sirens, afforded a unique opportunity for the exact galvanometric study of the emotions aroused by various kinds of noises. From the purely scientific point of view the opportunity could not be neglected of studying the psychophysical phenomena brought to our doors—phenomena that could not be expected again within the same lifetime. So from the air raid of September 21, 1917, to the last and most prolonged visit of Whitsuntide, 1918, I enlisted the services of volunteers to sit quietly, connected by wires to a galvanometer, and on two occasions I had sitters arranged in connection with recording apparatus which was set going a few minutes before the noise began, so that the emotive response during the whole affair was recorded. Let me show you two or three photographs (Figs. 2 and 3).

These photographs are not merely of interest on their human side, but also have this definite scientific value, that they afford measured records of the largest emotive responses that I have ever witnessed. The responses commonly observed in the laboratory are at most 10 per cent. changes; these air-raid responses have been at least 200 per cent. changes, which I cannot reproduce artificially by any means I care to employ.

7. But to return to our different classes according to sensitiveness. We classified people as positives and imaginatives according as they exhibited greater response to fact or to fiction. Apart from this criterion, we might undertake to arrange people as more or less imaginative according as they give larger or smaller responses to certain standard threats, as of

a pin-prick or the lighting of a match. High in the scale of imaginatives we not infrequently meet with people who can at will either keep quiet, or think thoughts and see visions and hear words of purely imaginary existence without objective physical substratum. It is very interesting to watch the galvanometric signs of subjective phenomena—interesting to the onlooker, but far more interesting to the subject who knows what he (or she) is thinking about. And when it is realised that the galvanometer answers to one's thoughts and temper, it becomes quite an absorbing pastime to sit quietly in an armchair and watch oneself think as one watches the galvanometer move.

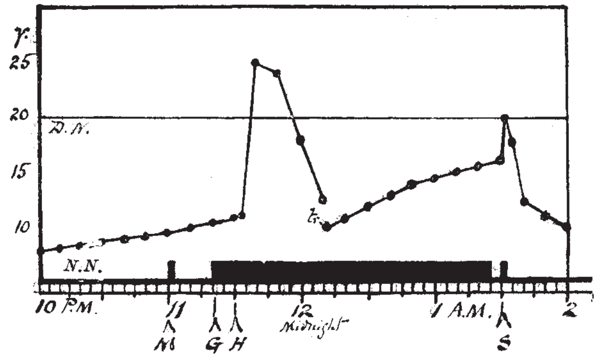

FIG. 2.—Emotivity of A. M. W. during the air-raid on Whitsunday, 1918. (From the *Lancet.*) M indicates the time of the first warning by maroons at 11 p.m. G indicates the commencement of gun-fire. The duration of the disturbance was from 11.20 p.m. to 1.30 a.m. H marks the moment of maximum alarm, when the swelling hum of approaching aeroplanes was most audible. S indicates the second warning by siren at the termination of the disturbance. The electrodes were transferred from the left to the right hand at 12.5. The horizontal lines D.N.-N.N. indicate the average normal day and night conductance of A. M. W., ascertained from other observations.

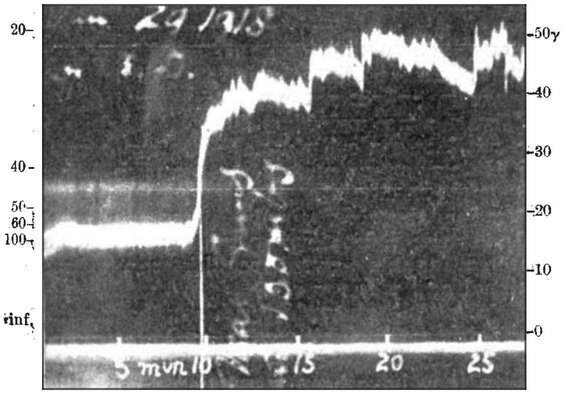

FIG. 3.—Galvanometric record of G de D. during the air-raid of January 29, 1918. (From the *Lancet.*) At the tenth minute of observation the noise of maroons, immediately followed by that of aeroplanes and guns, broke out, and the resistance, which was approximately 60,000 ohms during the first ten minutes before the disturbance, fell to approximately 20,000 ohms during the next 15 minutes. (On the left hand is given the resistance in thousands of ohms, and on the right the conductance in gemmhos.) The measurements are as follows:—

0	8.30 p.m.	56 × 1000	ohms or	18γ
5	8.35 ,,	53	,, ,,	19γ
10	8.40 ,,	27	,, ,,	37γ
15	8.45 ,,	22	,, ,,	45γ
20	8.50 ,,	20	,, ,,	50γ
25	8.55 ,,	20	,, ,,	50γ
At 11.30 (all quiet)		44	,, ,,	23γ

8. The emotive response is liable to all manner of variations. It varies in different individuals, and in the same individual it varies with different states of mind and body. It varies in magnitude and in its distribution over the limbs with variations in the magnitude of its exciting cause. While it is, in the main, an uncontrollable phenomenon, I call to mind more than one case where to all appearance it has been influenced at will.

9. The *distribution* of the response over the body is especially interesting. In normal persons it is exclusively palmar (and plantar); the rest of the body-surface is silent. But in "sensitives" it extends up the limbs and the trunk. And a border-land person, according to his state of temper, can react normally to-day, but as a "sensitive" to-morrow. The few spiritualistic mediums whom I have examined have (with one doubtful exception) given the reaction proper to "sensitives," *i.e.* in the hand and in the forearm.

10. The *diurnal variations* of the reaction attracted my attention at the very outset of the inquiry. I soon noticed that the same people, when submitted to a standard stimulus at different times of the day, gave responses of very different magnitudes; the responses were at their best about the middle hours of the day, when physiological activity is high, as compared with what was elicited early in the morning and late at night. And the conductivity of the palm of the hand rose and fell during the day (as does the temperature).

I thought it necessary to investigate this diurnal periodicity rather closely to learn how much it might be necessary to take into account the time of day when comparing results obtained on different individuals. So I watched this periodicity on my own hands by means of apparatus set up for the purpose in my dressing-room, so that observations of conductivity could be taken at any convenient time. The observations were recorded to form a graph on squared paper; and it may be remarked, by the way, that throughout the observations the conductivity of my right hand has been found to be higher than that of my left hand.

11. The three weeks over which these observations extended afforded me an admirable opportunity of observing the galvanometric effects of my own normal variations of "temper." Most people are more or less conscious of what may perhaps be called variations of euphoria before breakfast, and of very distinct, if not outwardly evident, variations of euphoria when the morning's letters are read. In order to test this point a photographic recorder was set up in connection with the galvanometer on my dressing-table and I had my letters brought up there and read to me and signalled on the recording plate. Most of the letters made no impression upon me, but I well remember one fortunate morning on which the post included two distinctly effective letters which produced marked effects duly recorded on the photographic plate.

12. One is naturally tempted to ask what relation there may be between the magnitude of the reaction and the mental quality. A first step towards an answer to this question has been taken by Miss Waller, who has made systematic measurements of seventy-three students of medicine, divided according to examination results into an upper and a lower division. The average response was higher in the former than in the latter—*e.g.* to disturbing questions the average value of the response came out about 50 per cent. higher in the upper division.[4]

13. I have often been asked whether pleasant and painful sensations produce similar or opposed galvano-

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[4] Mary D. Waller, "The Emotive Response of a Class of Seventy-three Students of Medicine measured in Correlation with the Result of a Written Examination," *Lancet*, April 6, 1918.

metric deflections. The emotive response in its unmistakable form as a sharp movement occurring about two seconds after its exciting cause is always in one direction, *i.e.* in the direction of decreased resistance —increased permeability, poro-dilatation or, if you prefer to think it so, contraction of living matter round pores so as to dilate them. And in many thousands of observations I have never witnessed any similar movement in the opposite direction—*i.e.* in the direction of increased resistance. All that is ever seen in that direction is the gradual remission of a previous deflection in the emotive or excitatory direction. If you regard the question in its psychological aspect, you will soon be satisfied that the matter could not be expected to come out otherwise. Our pleasures and pains are not simple opposites producing opposite physiological effects. Pains are active and exciting states in our conscious life, sharply contrasting with their background. Pleasure is more often merely the subsidence and relief from pain, a gradual recovery of the untroubled state. A pin-prick suddenly excites emotion, and the emotion gradually falls to rest. There is no counterpart pleasure equal and opposite to a pin-prick. Pleasure is of necessity gradual. Too sudden pleasure—joy, as we call it—is exciting, and causes discharge down the nerves that acts precisely like painful excitements and gives rise to electrical effects in the same emotive direction.

14. We distinguished a few moments ago between imaginatives and positives according as threatened pains produced larger or smaller effects than real pains. It is convenient to draw another kind of distinction according to the extent of body-surface over which the response is manifested. The response to "weak" stimuli in the great majority of men and women is exclusively palmar (and plantar). But with "strong" stimuli, and in certain cases with "weak" stimuli as well, the response can also be manifested by the forearm (and by the leg) as well as by the hand (and foot). Such cases may be designated as "sensitives" to distinguish them from the others who are relatively insensitive, but since these others are in a majority, and it would seem inappropriate to designate the majority of mankind as insensitive, it is better to call them "normals." These two labels, "sensitives" and "normals," are not intended to imply any division into two hard-and-fast categories, but rather a scale of differences grading between two extremes. Indeed, I have satisfied myself in at least one case that a subject classified at a first sitting as "normal" was temporarily raised to the degree of "sensitive" in consequence of a rather violent fit of "temper."

It is convenient to reserve the designation "insensitive" for cases low down in the normal scale, giving in response to ordinary stimuli little or no palmar reaction—*i.e.* a doubtful response of the order of 1 per 100 of the initial resistance.

15. Provisionally, then, our observations can be systematised in accordance with the following scheme:

Class.	Emotive Response.		Examples.
	Hand.	Forearm.	
I. Sensitives ... ("Imaginatives")	Yes	Yes	Spiritualistic mediums and others.
II. Normals ...	Yes	No	The majority of men and women.
III. Insensitives ... ("Positives")	No	No	Pythiatics. "Shell shock" cases.
IV. Others	—	—	"Shell shock" cases and others.

Class I.—"Sensitives" giving large responses (10 per cent. or more of the original resistance) from the forearm and from the hand.

Class II.—"Normals" giving moderately large response (2 to 5 per cent.) from the hand, but little or no response from the forearm.

Class III.—"Insensitives" giving little or no response (1 per cent.) from the hand, and, of course, also the forearm.

Class IV.—(*a*) Subjects who, by reason of their state of health, were obviously unfit to undergo examination, and (*b*) subjects who declared themselves as unable to stand it.

Subjects of Class I. and Class II. include those who were characterised a moment ago as "imaginatives." The three spiritualistic mediums to whom I referred just now were included in Class I. Class III. comprises people of duller imagination, or perhaps of firmer fibre, whom we called "positives."

At this early stage indeed, when the number of properly observed cases is so small and the danger of imperfect observation so great, it seems to me hazardous even to talk about rules and exceptions or to attempt a classification. Nevertheless, if the attempt is made without prejudice, and if the results of observation are recorded in physical units by the side of what in medical parlance is the clinical history of the subject, a preliminary classification is not only permissible, but also necessary.

Let me again refer to the present attempt and make good the point that we may expect to find the unexpected, that so-called regular results may be exceptional and *vice versa*.

16. *Pythiatics.*—Hysterical subjects or, as they are now called, "pythiatics," men as well as women, seem to be exceedingly sensitive and make a great fuss; but when they have been persuaded to sit still in an armchair and connected up with the galvanometer and tested by ordinary stimuli—pin-prick, false and real; match-burn, false and real—lo and behold! they exhibit little or no response. They belong to Class III., that of the "insensitives"; and we are reminded of the fact that in exaggerated—*i.e.* pathological—degree the hysterical or pythiatic state is found to include anæsthesia, loss of sensibility, as a leading symptom. But, of course, more observations are necessary, and more observers.

The Modern Londoner and Long Barrow Man.

At a meeting of the Royal Anthropological Institute held on March 8, Prof. F. G. Parsons read a paper on "The Modern Londoner and Long Barrow Man," in which he discussed a claim made by Dr. Macdonell and Prof. Karl Pearson that the head shape of Londoners of the seventeenth and eighteenth centuries was more like that of the Long Barrow men than of any other race. Prof. Parsons, however, showed, by a detailed comparison of contours obtained from thirty male London skulls of the seventeenth and eighteenth centuries dug up in the Clare Market district, and corresponding with the averages obtained by Dr. Macdonell from his London skulls found at Whitechapel and Moorfields, with those of twenty Long Barrow skulls from Yorkshire, Wiltshire, and Gloucestershire, that in the head measurements, in the depth of the orbital openings, in the length of the face, and in other anatomical details the London